ANALOGY BASED THINKING TECHNIQUES USED TO STIMULATE CREATIVITY AND INNOVATION

Dumitru-Octav Dafinoiu, PhD Student, University of Bucharest

Abstract: The creation of knowledge, the advanced research in strategic directions, the increasing of economic competitiveness and the transfer of knowledge in the economy are priorities of economic policies.
They are based on research, development and innovation activities, which although take various shapes, have something in common: they relate to problem solving. Strategies, methods and techniques used in order to find solutions for problems are based on problem solving techniques taken from psychology.
This paper, which creates a bridge between the field of economy and that of psychology, proposes innovative tools to stimulate creativity and the problem solving ability. The tools suggested are based on analogy, the fundamental operation of thinking and creative imagination, and can be applied in various business functions.

Keywords: ***creativity, problem solving, analogy, innovation, economy.***

JEL Classification:*O310 Innovation and Invention: Processes and Incentives*

Innovation As An Objective For Public Strategies

As European Commission's General Directorate for Research and Innovation highlights in the 2014 report, the European Union is presently facing a existential challenge: to achieve a sustainable growth using disruptive technologies.

In order for this to be achieved, the European research – innovation centers and the organizations from various fields must develop and implement a new paradigm: the collaborative ecosystems This type of ecosystems, creating added value through knowledge and ideas, and innovation are thus strategic objectives.

When proposing possible scenarios of exiting the crisis, the executive summary of Europe 2020 Strategy (p.7) stresses that Europe can succeed and mentions as the most important resource the talent and people's creativity. In this new context, the policies from the European Union countries are aligned with the European strategy and, particularly, with Horizon 2020 - the Framework Programme for Research and Innovation.

The Romanian Strategy for Research-Development-Innovation 2014-2020 has three objectives of strategic importance - 1) to increase the competitiveness of the economy through innovation, 2) to increase the national contribution to knowledge, 3) to increase the role of science in society. The Strategy also stipulates priorities regarding the interdisciplinary research and development.

Innovation represents the most important source which generates welfare and it is fueled primarily by research and development.

Links Between Problem Solving, Research and Development, Innovation

The innovation theory was developed through the work of authors like J. A. Schumpeter, C. Freeman, J. Schmookler, B.V. Hippel, G. Saint-Paul, D. C. Mowery, N.

Rosenberg, R. R. Nelson, R. Rothwell, R. H. Smiley, B.A. Lundvall, just to name only a few. They covered a diversity of topics. They have studied the factors that determine innovation, the types of innovators, the sources of financing in innovation, the impact of innovation on economic performance of organizations.

When analyzing the innovation activity inputs one starts from the observation that such activities are specific to the research and development (R&D) function within an organization. While the activities specific to the R&D function might have different forms, they also have a common denominator: they are connected to problem solving.

According to Frascati Manual, the R&D activity consists of "creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications.(p.30). The same manual mentions that the R&D concept comprises of three types of activities (p.30): fundamental research, applied research and experimental development. The first type of R&D activities aims to acquire new knowledge about phenomena and facts, irrespective of practical applications. Applied research, which is also an investigation held in order to gain knowledge, aims primarily to achieve practical objectives, applicability related to the respective knowledge. Experimental development is a systematic work, fundamented on the knowledge gained from research and practical experience, directed towards producing new objects (either materials, or products, or devices etc.) or new processes, systems and services, or substantially improving those which already exist.

As mentioned earlier, the R&D activities have a common denominator in problem solving. Different strategies, methods and/or techniques are used in problem solving in order to arrive to solutions. Strategies, methods and techniques used in order to find solutions for problems are based on problem solving techniques taken from psychology. Problem solving is one of the most important activities of thinking, having an essential adaptive role. In problem solving, through processes like restructuring and the reorganization of the problem-situation field, the initial unresolved contradiction is to be integrated within/with the already existing individual's cognitive - operative structures.

During the problem solving process the next sequence of stages is to be followed: identifying and defining the problem, identifying and choosing a solving strategy, organizing the knowledge about the problem and about the steps needed to be followed, identifying existing and necessary resources and ways in which they will be accessed, monitoring the process from the initial stage to the solution, evaluation of the results.

The actions that a person can take to achieve a goal are defined by Polya (1954) and Ormrod (1999) as operations. The respective set of actions bind the problem's details to the desired results. Authors like Tuma and Reif (1980), Wilson and Clark (1988), Bender (1996), Payne and Wenger (1998) refer to the problem space - as the space which contains all the possible states of the respective system. The problem space includes all the possible objectives and ways to achieve these results.

In order to identify possible solutions and achieve the desired results, various techniques and strategies are used. Among them, we mention: trial and error, hypothesis testing, brainstorming, "divide and conquer", lateral thinking, analogy, etc.

Analogy As A Strategy to Stimulate Creativity And Problem Solving

The operation of analogy is a fundamental one for both thinking and creative imagination. The term "analogy" originates from the Greek words "ana" (meaning "on", "according to", "form") and "logos" (which means, among other things, "word", "thinking", and "fraction ").

According to Ashworth (2013), in the mathematics of Pythagoras (580-495 BC), about 2600 years ago, analogy was a formula with two proportions, having four unequal terms, in respect of equality. Subsequently, Plato and Aristotle (Apud. Ashworth, 2013), considered that analogies are legitimate as a consequence of the use of inductive generalization. They have explained the analogy as a shared abstraction concerning two terms submitted to attention. This abstraction could consist not necessarily in a relationship, but also in an idea, a model, effect, etc.

Aristotle, which developed the theory of Plato, made distinctions between analogy and identity and between analogy and correspondence. He extended the applicability of analogy to other domains. His theory was adopted by philosophers, theologians and jurists and thus, over time, the four unequal terms forming two proportions that are equal expanded to other domains, expressing the correspondence between objects or phenomena in different fields of knowledge.

The fact that this correspondence could be expressed through a variety of factors and could bind objects from very different fields gives the analogy a remarkable potential regarding the creativity and imagination.

We can talk about analogy when, having in attention two objects in different domains, we observe some similarities between them, a certain parallelism, a symmetry regarding their model of organization and/or between the relationships of their constitutive elements. Based on this parallelism or these similarities we can draw inferences and, thus, understand the less familiar domain (or object) through the more familiar one. However, the equivalence could be one of a partial nature so, after we draw the assumptions, we must determine if they are true or false.

In other words, based on the observed symmetries regarding the form, the function and/or structure of the two objects in different domains, one being familiar to us (and, for this reason, being called source or object/domain source) and the other (called target or object/domain target) we are not familiar with, we identify a relatively common model of organization and/or operation of the two objects, and based on this fact we can draw inferences regarding the target object. The correspondences between the source and the target can go to deeper levels not only to superficial aspects. For instance, the similarities could refer to the component elements of the objects, but also to relationships between them and even to relations between relations. When a certain relationship between two components of the source corresponds to a certain relationship between two elements of the target object ,we speak about relations between relations.

The most influential theory regarding the operation of analogy is Structure-Mapping Theory in which, when drawing (or mapping) the correspondences between the source and target objects (or relations), two essential principles must be followed: one-to-one correspondence and parallel connectivity.

The principle of one-to-one correspondence states that an object from the source must have only one correspondent object from the target and vice-versa.

The principle of parallel connectivity states that the relationship between some objects of the source domain must correspond in the target domain between the same objects corresponding one-to-one to the source objects previously mentioned.

Only if the source and the target domains are aligned in such way, following these two principles, then we can proceed to draw assumptions about the target domain. We can talk about an analogy only when the correspondences can be found at two levels: the level of simple relationships - meaning the relationships between objects, and the level of secondary relations - meaning the level of relations between relations. In such a case, the correspondences are valid but, most of the time, it is very difficult or even impossible to discern the relationships between relations concerning the target. For this reason, the assumptions drawn (or at least part of them) may be, in the end, invalidated.

But even so, the analogical reasoning can help scientists to gather important understandings about the target domain, being guided by the partial equivalencies.

Another influential theory about the analogical reasoning is the Theory of Pragmatic Schema and Multiple Constraints. It has been developed by Holyoak and Thagard (1989, 1996). This theory gives the structural similarity (Holyoak and Koh, 1987) an essential role in establishing the degree of overlap between the source and target and keeps the process of mapping the common abstract relations between the source and the target as being one of a central importance.

The authors identify three types of constraints which are perceived not in a rigid way but as favoring or inhibiting pressures in the process of aligning the corresponding pairs. The systematicity principle is seen as a structural constraint. The pragmatic constraint relates to the goals and objectives of the individual and, thus, influences the choice of relevant similarities between the source and the target domains. The semantic constraints consist of assessments of the degree to which the source and target objects are perceived to be similar.

Runco and Pritzer (2011) conclude that the analogical reasoning process must follow the next steps: detecting a target object or domain, identifying the source object or domain, mapping the correspondences between pairs of source elements and target elements which we assume to be alike, the evaluation of the adequacy or inadequacy of the proposed analogy, formulation of assumptions starting from source-object elements and their attributes to the ones of the target object.

If the conclusion we draw is that we have made inappropriate correspondences, we must resume the process, or we could keep some relevant mappings and will resume the process with other domains/objects.

Presently, the analogical reasoning constitutes the point of focus of many important authors which are studying it extensively, mainly in relation with the activity of software development.

In the field of science, the operation of analogy is used especially as a thinking operation while the artists, the designers, the engineers, the architects, the people from R&D departments, the marketers and communicators are using it mainly as an operation of creative imagination.

The fact that the subject has a high degree of freedom in choosing the source and target domains gives the analogy an important creative-imaginative valence. When the source and target domains are further away from each other, the result has a higher likelihood to be creative, original, unique. It is also recommended for the two domains to be different or even uncommonly associated, since the aim of the creative-imaginative process and the one of the thinking process are also very different. When analogy is used as a creative operation, the mapping of correspondences might require a systematic approach; but objects, attributes and relationships can be processed in various ways and mapped by different criteria, for example symbolic and/or aesthetic ones. Also, the individual can apply transformations, distortions, modifications and re-significations in order to generate new items.

Paradigm Changes Based on Analogies, With Significant Impact on Scientific And Social-Economic Level

Imagination, creativity and human thinking are the fundamentals of all major discoveries, famous inventions and significant ideas of our history. The operation of analogy is essential both for thinking and creative imagination and it has inspired many remarkable people in their approaches to solve important problems of humanity.

We will discuss here some examples and see how analogies shaped our history through paradigm changes that lead to discoveries, inventions and innovations with significant impact on scientific and/or social-economic level:

According to Boden (1991), the German chemist August Kekulé (1829-1896) was sitting in his room when he saw in the burning fire from his fireplace "a snake that kept his tail in his mouth" (p.16). In that period (the year 1865) he was searching for the chemical structure of benzene and he supposed that benzene, like all the other molecules discovered before, was linear. However, he abandoned this assumption when he saw the
dancing flames that looked like circular snakes biting their tails and reasoned by analogy, asking his self if benzene could have a circular molecule. Thus, he radically changed the field of chemistry.

A half of a century later (in the year 1911), the physicist and chemist Ernest Rutherford made another remarkable analogy by comparing the solar system with the atom. At that time, the structure of the atom was not well known. Rutherford perceived a parallelism between planets and electrons, and between the Sun and the core of the atom. Despite the obvious contrast in scale, and based on the similarities he saw, he drew the assumption that, at the atomic level, there must be a correspondent force to the force of gravity in the solar system.

Later on, with theoretical and empirical means, Rutherford and physicist Niels Bohr have tried to detect any evidence of this model of structure. Wilson (1983) tells us how Rutherford and Bohr collaborated in this direction. Bohr (1913) also used the model of the solar system to think analogically about the quantum model of the hydrogen atom. The model was named Rutherford - Bohr, in appreciation of the importance of their discovery and their work.

The analogy also revolutionized some industries, not only science.

In the 1870s, many inventors who were seeking success were attracted by the potential of a new technology - electricity. In the year 1870, Alexander Graham Bell moved from

London to North America and in 1872 got a job at Boston University as a specialist of Vocal Physiology. At that time, inventors were searching for a solution to transmit several messages simultaneously through the same telegraph cable. The idea to transmit voice by wire was considered purely theoretical. In the year 1872, Bell was working on both projects. Two years later he reasoned by analogy between the nature of sounds and the current telegraph used to transmit information. At the time, the telegraph was using alternating current to transmit information and Bell realized that an undulating current would be more appropriate. On February 14, 1876, Graham Bell filed an application at the Patent Office to register his invention and a year later transformed it into a successful business.

As it is known, for inventing the phone's membrane, he also made an analogy, this time with the human ear. In his work he was using the phonoautograph – a device invented by Leon Scott to record speech vibrations. The human ear model and the phonoautograph one have served as a main source of inspiration in making a calf intestine diaphragm, which reached a magnetized metal arm that vibrated due to its proximity to an electromagnet connected to the cable which transmitted the message.

Another industry, another revolution: a few years later, in 1913, Ford Motor Company had inefficient processes and a very ambitious goal - to produce cars for millions of Americans.

Hounshell (1984) describes the transformation at the Ford plant. One of the company's machinists, William Klann, examined a new model of industrial activity at a slaughterhouse in Chicago. That activity had an increased efficiency: butchers were aligned and executed specialized tasks on advancing meat carcasses hanging from a mobile chain. The domains were different but William Klann saw some similarities between the processes of constructing an engine and cutting pieces from carcasses. He noticed that in one case it was a process of dis-assembly and assembly in the other one.

Seeing how efficient was the process at the slaughterhouse he thought that this model could be adopted also in the car industry. Klann urged his boss and the assembly line model entered a test phase. Eight months later the assembly lines were implemented in connection with all parts of an automobile, including the chassis, which lead to an increase in productivity of up to 1000%. This allowed to dramatically decrease the price of Ford`s T Model to almost a half. In the context in which, on the market the prices were rising, Ford reached in eight years a 50% share of the market.

This invention was named the "leverage that moves the world" (Apud. Hounshell, 1984, p.10) by Joseph Allan Nevins, an important journalist at the time. Mass media has intensely promoted the assembly line invention and the success it has shown at Ford Motor Company and this lead to its adoption in numerous other industries.

Here's another example, this time from the present: Professor Henry Markram of Ecole Polytechnique Federale de Lausanne leads the Human Brain Project - an international initiative which will simulate the processes of a human brain using the Blue Gene supercomputer from IBM. This is probably the most important project in the field of neuroscience.

IBM developed a complementary project starting from the analogy with the modality of transmitting information through synapses. After the researchers from IBM have developed

two prototypes of cognitive chips - one containing 262,144 programmable synapses and the other 65536, in August 2014, IBM created a chip with 1 million neurons and 256 million synapses. These types of chips are the fundamental parts of cognitive computers which will be able to model the human brain: learn from experience, find correlations and think.

Techniques Based On Analogy Which Stimulate Creativity and Problem Solving

The analogy is used in many domains, often intuitively, due to the fact that individuals use diverse personal experiences when faced with new situations. The simplicity of analogy favors a sufficient understanding so as to be used in different situations or environments.

However, a more efficient way to use analogy is when the analogical thinking process is followed on a systematic base. Such techniques bring out its potential to increase the performance in thinking, in problem solving and in creative imagination.

Synectics is probably the most well known technique based on analogy. It was invented by W.J.J. Gordon (1961) and developed with George M. Prince. Synectics works as a problem solving technique by stimulating creativity at a group level. By 1950, the two researchers have studied thousands of hours of recordings of the activities carried out within the groups. They wanted to identify exactly what were the aspects which helped people to become more creative and also to successfully implement the ideas generated within the creative process. They concluded that the quality of the innovation process depends on the quality of the social climate, the thinking process and behaviors (Apud. Nolan, Williams, 2010). This is why the procedures applied in Synectics ensure a protective, non-judgmental and non-critical working climate for the indviduals in the group, in order to better direct their energy in a constructive way towards solving the situation.

Thinking and creative processes involve expanding the frontiers of ideas by using what in Synectics is called Spectrum of thinking (Apud. Nolan, Williams, 2010). This implies a delimitation of spheres of thinking which move away from the problem space. This process of idea development is characterized by openness, risk taking, ambiguity, interruption/generation of new connections, the use of analogies and metaphors, and the use of absurd thinking and/or of the apparent lack of relevance. Synectics practitioners use the trip technique - an analogy between a trip for recreation purposes and the distancing from the initial problem field. The reasoning passes through "layers" of thought like diversity, desire, analogy/metaphor, nonsense/irrelevancy.

When sufficient new ideas have been generated, the group focus will get back on the problem, but with a fresh look and a new understanding, forcing associations between apparent irrelevant ideas and the problem, creating new connections, which thus make them more able to generate promising ideas to solve the problem. The selected promising ideas will be analyzed and systematically improved in feasibility.

The TRIZ technique was developed by G. S. Altshuller and his colleagues between 1940-1970. It is a unique philosophy on technology and creative thinking and includes a vast amount of examples that were analyzed and upon which the methodology was developed. Thus resulted the "Matrix of contradictions" which is a database with cases of contradictions and the methods used to solve them. The technique includes 40 types of operations that can be applied to find creative solutions to engineering and/or technology problems. Here are some

of them: division, removal, asymmetry, universality, merging, counter-weight, preliminary action, reversing, dynamic partial or excessive action, adding a dimension, vibration, periodical/continuous action, intermediate.

In TRIZ, the problem is understood as a contradiction between the situation and the need. According to Nakagawa (2004), TRIZ essence consists in perceiving the problem as a system, then define the ideal solution and resolving existing contradictions. In order to define the ideal solution is very useful to analyze the trends of evolution of the system problem, of its subsystems and of the supra-system in which the system problem is included.

The method used for solving the contradiction is actually the pattern of relations to be transferred analogically. Basically, a system of relationships is identified in a domain (source) and categorized and, after that, it is used in other areas (target).

TRIZ uses also a database called "Effects Database" which is a collection of physical, chemical, mathematical effects etc. Thus, the knowledge and the techniques from one domain could be applied analogically to another domain.

The ASIT technique (the Advanced Systematic Inventive Thinking) evolved from the art and science of TRIZ. Horowitz (1999) fundamented her technique on the following major principles: "thinking inside the box" – only what exists in the system could be used to solve a problem , "qualitative change" - the main problem is removed or altered in such a way that its effect becomes beneficial, "the maximum resistance path" - counter-intuitive thinking has a high probability to generate novelty, originality.

The 40 operations from TRIZ were reduced in ASIT to only 5: suppression, multiplication, division, unification of tasks, dependent attributes.

Innovative Analogy Based Techniques Proposed for Stimulating Creativity and Problem Solving

The "Playing field" technique (Dafinoiu, 2013) is based on an analogy between the problem situation and a playing field. These parks are miniature universes in which a multitude of elements can be used as resources in problem solving processes, or for generating creative concepts.

Having this in mind, analogical meanings will be assigned to the constituent parts of the playing field, taking into account the roles they genuinely meet in the assembly. The technique uses two sets of instruments: one for better organizing the initial situation, and the other to apply transformations. The technique is used in writing.

In the first stage, the person will organize the problem in three types of entities: Objects, Attributes and Relations (OAR). The objects are the component elements of the problem situation. The attributes are the characteristics of the objects. In the Relations category we include: relations between objects, relations between characteristics and also relations between objects and characteristics or relations between relations. It is preferred that these columns are written on the same page and in the most concise manner possible, keywords recommended.

In the next stage, the person will organize and analyze the problem situation in writing, following the logic of the playing field`s design. Thus, the elements which form the infrastructure of the park will be assigned meanings that orient the thinking process towards

the problem situation and its context and, also, towards the understanding of their implications:

- "The Benches" represent a moment of pause to remember the achievements. Sitting on the bench, we distance ourselves from the present to project the ideal scenarios, when the problem is solved.

- "The Light poles" orient our attention on what needs to be clarified and verified, and on the positive aspects and opportunities. The metaphor that guides us is "shed some light on the issue".

- "The Dustbins" direct our attention to elements that we consider unimportant and delay us from solving the problem, elements which need to be isolated. After we make the final decision we may analyze again those elements and see if they are useful.

- "The Guard`s cabin" - symbolizes caution. Here we direct our attention to the weaknesses and threats of the problem situation and of the possible options that are available to us for solving the problem, and all other aspects that need our special attention as well. We will also figure out how to avoid the threats or how to act in case they cannot be avoided and, also, who/what may offer protection and in which conditions.

- "The fences and other dividing elements" often signify the limits, limitations and borders of the situation or of the options we have to solve the problem. We also need to consider rules, laws, principles, etc.

- "The bridges" symbolize connections with similar situations or problems from the present, the past, (regardless of the place or the domain) but it can also signify a liaison to the resources that we can employ to help us solve the situations and problems.

- "The alleys" signify the directions, the possibilities/opportunities and ways to finding the right solution.

- "The green spaces, the spaces with flowers, the trees": Flowers guide our attention toward the aesthetic side of life, towards aspects related to art, towards the harmony and the natural state of the human being: creativity. In this position, we propose new ideas, we appreciate values. The trees signify implications, creative development, possibly even artistic. They can also lead us to think about personality.

In the third stage, the person should systematically track which new relevant aspect the previous stage has brought. They will be highlighted in the table with OAR categories, depending on the category they belong, with keywords.

In the fourth stage transformations will be applied to the elements from the table, using the second set of tools. The person will imagine a certain path in the amusement park and each play area will have a certain operation associated with it (Dafinoiu, 2013, pp.43-44). For example, the slide corresponds to the amplification operation, and the sandbox corresponds to the suppression/omission operation. If the person has chosen these play areas then he/she will systematically apply these operations on each entity in the OAR table and imagine the system`s design in the new conditions. Examples: what would happen if the entity x in category A would be amplified? What would happen if the entity y in category O would be omitted/ suppressed?

This technique uses the following operations: analogy, association/combination, schematization, amalgamation, adaptation, substitutive imagination, typification/

modification, substitution, transposition, inversion/rearrangement/restructuring, amplification, additions/reduction, suppression/omission, division/ multiplication.

In the fifth stage, based on the new understandings gained regarding the problem and its entities (OAR), the best ideas for the resolution are selected and the possibilities to maximize the feasibility of these ideas are analyzed.

Conclusion

Problem solving is essential for the economy and it is also necessary in any other domains of activity. Regardless of the domain in which it is used, problem solving involves changes, restructurings, reorganizations at the level of the problem and it is based on cognitive and imaginative-creative processes. Problem solving techniques initially aim to define the problem and the desired results and then aim to deepen and/or expand the problem field in order to identify the necessary resources for solving the contradictions and the steps to be followed.

Analogical reasoning has had a great impact in science and economy. Problem solving techniques based on analogy utilize cognitive-operational schemes from other situations and/or domains and also the freedom to choose which entities are analogically mapped, operating with different levels of depth of the equivalence. Synectics, TRIZ and ASIT are some of the most representative problem-solving techniques based on analogy and they are thus widely utilized.

The "Playing field" technique operates with an analogical framework which systematically deepens and extends the problem situation field and which becomes stimulating from the imaginative creative point of view through the re-significations that it produces. In this framework, transformation operations on the entities of the problem are then systematically applied, in order to generate mental restructuring and reorganizations. The mental flexibility thus gained helps identify solutions through original combinations of entities and actions of the problem field.

Besides the possible improvements in the methodological chapter, in the immediate future the technique is to be investigated statistically for validation.

Acknowledgment

This paper has been financially supported within the project entitled **„SOCERT. Knowledge society, dynamism through research”**, contract number POSDRU/159/1.5/S/132406. This project is co-financed by European Social Fund through Sectoral Operational Programme for Human Resources Development 2007-2013. **Investing in people!**

REFERENCES :

Ashworth, E. J. (2013) *Medieval Theories of Analogy*, The Stanford Encyclopedia of Philosophy (Winter 2013 Edn), Edward N. Zalta (ed.), accessed at http://plato.stanford.edu/entries/analogy-medieval/, January 20, 2014.

AT&T, *Inventing the Telephone*, accessed http://www2.iath.virginia.edu/id/AGB/index.html, November 20, 2014.

Bender, E. A. (1996) *Mathematical methods in artificial intelligence*, IEEE CS Press, Los Alamitos, CA, USA.

Boden, M.A. (1991) *The Creative Mind – Myths & Mechanisms*, Basic Books, New York.

Bohr, N. (1913) *On the constitution of atoms and molecules*, Philosophical Magazine, XXXVII, Series 6, p. 476-502, accessed http://www.fisica.ufpb.br/~jgallas/CURSOS/Estrutura02/bohr_part02_PM1913_14786441308634993.pdf, November 30, 2014.

Ecole Politechnique Federale de Lausanne (2014) *Blue Brain Project* accessed http://bluebrain.epfl.ch/, November 29, 2014.

European Commission (2010) *Europe 2020 A European strategy for smart, sustainable and inclusive growth*, accessed http://ec.europa.eu/eu2020/pdf/COMPLET%20EN%20BARROSO%20%20%20007%20-%20Europe%202020%20-%20EN%20version.pdf, January 15, 2015.

European Commission (2014) *Boosting Open Innovation and Knowledge Transfer in the European Union*, accessed http://ec.europa.eu/research/innovation-union/pdf/b1_studies-b5_web-publication_mainreport-kt_oi.pdf, January 15, 2015.

Dafinoiu, O. (2013) The analogy – strategic resource in organizations` management. Bachelor degree. University of Bucharest, Faculty of Psychology and Educational Sciences.

Gentner, D. (1983) *Structure-mapping: A theoretical framework for analogy*, Cognitive Science, no.7, pp. 155-170.

Holyoak, K., Thagard, P. (1989) *Analogical Mapping by Constraint Satisfaction*, Cognitive Science, no.13, pg. 295–355.

Holyoak, K. J., Thagard, P. R. (1996) *Mental leaps. Analogy in creative thought*, MIT Press, Cambridge.

Holyoak, K. J., Koh, K. (1987) *Structure and surface similarity in analogical transfer*, Memory & Cognition, no.15(4), pg. 332-340.

Horowitz, R. (1999) *Creative Problem Solving in Engineering Design - Thesis submitted for the degree of "Doctor of Philosophy"*, accessed http://www.asit.info/Creative%20Problem%20Solving%20in%20Engineering%20Design,%20thesis%20by%20Roni%20Horowitz.pdf, January 20, 2015.

Hounshell, D.A. (1984) *From the American System to Mass Production 1800-1932 - The Development Manufacturing Technology in the United States*, The Johns Hopkins University Press, Baltimore.)

IBM (2014) *Neurosynaptic chips*, accessed http://www.research.ibm.com/cognitive-computing/neurosynaptic-chips.shtml#fbid=1O0BX1fFybF, November 29, 2014.

Nakagawa, T. (2004) *Problem Solving Methodology for Innovation: TRIZ/usit. Its Philosophy, Methods, Knowledge Bases, and Software Tools*., The TRIZ Journal, accessed http://www.triz-journal.com/problem-solving-methodology-innovation-trizusit-philosophy-methods-knowledge-bases-software-tools/, January 29, 2015.

Nolan, V., Williams, C., (2010) (Eds.) *Imagine That! Celebrating 50 years of Synectics*, Synecticsworld®Inc.

OECD (2002) *Frascati Manual - Proposed Standard Practice for Surveys on Research and Experimental Development*, accessed http://www.tubitak.gov.tr/tubitak_content_files/BTYPD/kilavuzlar/Frascati.pdf), February 20, 2015.

Ormrod, J. E. (1999) *Human learning*, 3rd edn., Prentice-Hall Inc.

Polya, G. (1954) *Patterns of plausible inference*, Princeton University Press, Princeton, NJ, USA.

The Romanian Government (2014) *Decision nr. 929/October 21, 2014 regarding the approval of National Strategy for Research, Development and Innovation 2014-2020*,

accessed http://www.cdi2020.ro/wp-content/uploads/2014/10/HOT%C4%82R%C3%82RE-nr-929-din-21-octombrie-2014-privind-aprobarea-Strategiei-na%C5%A3ionale-de-cercetare-dezvoltare-%C5%9Fi-inovare-2014-2020.pdf, February 20, 2015.

Rubin, J. (2013) *The Invention of the Telephone*, accessed http://www.juliantrubin.com/bigten/telephoneexperiments.html, November 20, 2014.

Runco, M.A., Pritzer, S.R. (2011) *Encyclopedia of creativity*, 2nd edn., vol. I A-I. Academic Press, Londra-New York-Amsterdam-Paris-Singapore-Tokyo-San Francisco-Sydney.

Tuma, D. T., Reif, F. (1980) *Problem solving and education*, Lawrence Erlbaum Associates, Hillsdale, NJ, USA

Wilson, D. (1983) *Rutherford: Simple Genius*. The MIT Press , Cambridge, MA, USA.

Wilson, L. B., Clark, R. G. (1988) *Comparative programming language*, Addison-Wesley Publishing Co., Wokingham, UK.